908

N94-36415

AN AUTOMATED DIGITAL DATA COLLECTION AND ANALYSIS SYSTEM FOR THE CHARPY IMPACT TESTER

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Abstract: The standard Charpy Impact Tester has been modified by the addition of a system of hardware and software to improve the accuracy and consistency of measurements made during specimen fracturing experiments. An optical disc, light source and detector generate signals that indicate the pendulum position as a function of time. These signals are used by a computer to calculate the velocity and kinetic energy of the pendulum as a function of its position.

Key Words: Charpy, fracture energy, impact testing, automated data collection, experimental errors.

Prerequisite knowledge required:

To meet the first objective, the student should be familiar with fracture testing and very basic use of computers. To meet the second and third objectives, the student should be familiar with basic analog and digital electronics, computer interfacing, experimental error analysis and simple BASIC programming.

Objectives:

This work was undertaken to explore three areas of materials experimentation. The most obvious first objective was to add instrumentation to significantly improve the accuracy of fracture measurements made with a Charpy impact tester. Measurements

made with the uninstrumented Charpy are performed by visually observing the maximum height achieved in the upswing of the pendulum after the fracture is completed. Depending on the energy required for fracture, the final position of the pendulum may be anywhere on the 26 inch long scale inscribed on the machine's circumference. Since the approximate final point where the visual observation is to be made is unknown, it is difficult to make an accurate determination of its final position. The uncertainty of carefully made visual measurements is approximately 1 to 2 in-lb[1] (.113-.226 J).

The second objective was to provide a platform for students to discover and study problems inherent in all instrumentation and automated data collection systems. This system has three modular sections: the sensor and its analog conditioning electronics; the digital circuitry and digital input-output interface to the computer; and the computer program (algorithmic technique) which accumulates, evaluates and displays the experimental data. Each of these modular areas (and problems which must be addressed within them) can be studied in isolation.

The third objective was to provide a mechanism to allow students to redesign part of the instrumentation to study different aspects of the fracturing experiment and to minimize certain errors in making and evaluating measurements. The initial configuration provides a measurement of the pendulum's kinetic energy prior to and subsequent to the fracture of the sample. The three modules were designed to optimize these two measurements. If one wanted to study the process of the fracture as it occurred, changes to each of the three modules would be necessary. This system was designed to make it easy for students to experiment with various alternatives to each of the three modules.

Equipment and supplies:

Needed supplies include: a Charpy impact tester, an Intel based personal computer, a digital input-output interface card; and various discreet physical and electronic components (described in detail below).

[1]The units of in-lb are used because the Charpy is labeled in in-lb. SI units are included parenthetically.

Procedure:

Modification of the Charpy - An optical position detection system was constructed and attached to the Charpy. This system consists of three sections: the optical position disk, the light sensor, and the signal conditioning circuitry. The optical position disk is an aluminum disk mounted on the pendulum axis and rigidly attached to the pendulum arm. Physical details of this disk are given in Appendix 1. The light sensor section consists of a light emitting diode and photosensitive transistor situated such that the optical position disk can allow or interfere with the light link between them. The signal conditioning circuitry serves to drive the light sensor section and to generate a digital TTL signal suitable for input to the computer input-output interface card. Physical and electrical details of the light sensor and signal conditioning circuitry are given in Appendix 2.

The signal generated by the experimental apparatus is coupled to an Intel based personal computer through a generic interface card. The computer program which controls the experiment directs the operator in the setup of the Charpy, acquires the experimental data, measures the times between signal pulses, computes and displays physical parameters including velocity and kinetic energy of the pendulum just before the fracturing impact and just after the fracture.

With an unmodified Charpy, an experiment is conducted by raising the pendulum to a standard position to the right of center and then releasing it. The pendulum swings down, breaks the sample and continues up to the left of center. The observer watches and notes the value on the inscribed scale at the position where the maximum height is reached by the pendulum to the left of center.

With the modified Charpy, the energy used to break the sample is determined by measuring the velocity of the pendulum's mass immediately prior to and subsequent to the fracturing of the sample and then computing the loss in total energy.

Theory - The work done in fracturing the sample can be found by measuring the total energy lost by the mass affecting the fracture. The total energy in the pendulum's mass is:

$$1/2mv^2 + mgy \qquad (1)$$

where m is the pendulum's mass, v is its velocity, and y is its height above its minimum altitude. The measurement of initial velocity and final velocity were made very near the pendulum's minimum altitude and equally displaced from that position. y_f and y_i are very small and are equal. Therefore, the total energy used to break the sample is:

$$1/2m\left(v_f^2 - v_i^2\right). \tag{2}$$

The signal generated by the optical circuit is of the form below:

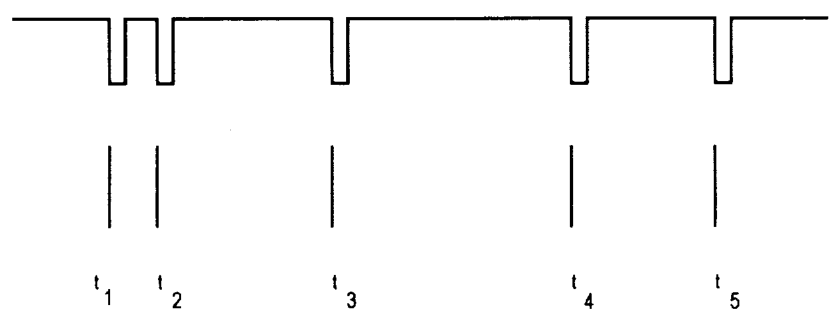


Figure 1

The computer looks for falling edges in the incoming signal. The first edge at t_1 starts the computer's timing function. The computer measures the time between t_2 and t_3 which are generated by two slits just prior to the pendulum contacting the sample. The breakage occurs during the interval between t_3 and t_4. The computer measures the time between t_4 and t_5 which is generated by two slits just subsequent to the break. Since the position of the pendulum's mass is accurately known when each of the slits generates its signal, the velocities of the mass can be accurately computed.

Analysis of data collection errors - The principal source of measurement error in this experiment is the quantitizing error in measuring time. The computer must count time in discreet steps. If an event occurs between count 5 and 6, it is not possible to know whether the event occurred just after the counter became 5 or just before the counter became 6. The impact of this quantitizing error depends on the size of the time steps being counted. If the counter increments every 0.1ms, the error would be an order of magnitude greater than if the counter increments every 0.01ms.

In our case, the counter is incremented every 0.021 ms. Physical dimensions of the modified Charpy are such that 676 counts occur in the time between t_2 and t_3. Since the actual time of t_2 could be almost 1 count from the time it is detected and the actual time of t_3 could be almost 1 count from the time it is detected, the interval t_2-t_3 as measured by the computer could differ from reality by as much as 2 counts or 0.3%.

Several interesting student projects could be designed around the determination of the effect of other errors introduced by physical aspects of the machine such as: accuracy of the position of the mass at t_2, t_3, t_4 and t_5; accuracy of measurement of the pendulum's mass.

***Modifications for equipment improvement* -** The next logical step for this experiment is to add more optical slits and to make them thinner and closer together. A velocity measurement could be made as each slit passes thereby giving a graph of velocity (energy) as a function of position as the pendulum mass breaks the sample.

***Conduct of fracture experiments* -** Experiments which have been successfully completed include measurement of the fracture energy of wood samples both with and against the grain; the fracture energy of wood samples as a function of water content; and the fracture energy of wooden samples which have been fractured and then glued together with various types of glue. Wood samples were used because they are readily available, easily worked and inexpensive. Polymers, ceramics and composites could also be tested by this method.

Sample data sheet:

Calibration Check: (Run with no sample in place)

Initial speed:	3.534 m/s
Initial kinetic energy:	5.666 J
Final speed:	3.534 m/s
Change in KE	-1.02 (10^{-3}) J

Sample Type: Pine (white)
Orientation: with the grain
Dimensions: 1.35 x 1.25 x 5.5 cm

Sample #	Fracture Energy (J)
1	2.00
2	2.57
3	2.28
4	1.54
5	2.00
6	3.43
7	2.28
8	1.99
9	2.25
10	1.99

Instructor notes:

Conducting experiments on the unmodified Charpy was frustrating to most students. Two students were required, one to accurately position the sample and to release the pendulum. The second student would observe the highest position of the pendulum after it fractured the sample. Typically, several trial fractures were necessary to determine the approximate location of the maximum position of the pendulum after the fracture.

With the addition of the automated data collection system to the Charpy, experiments can be conducted by a single student in less than half of the time previously required. The accuracy of the measurements achievable has been improved ten-fold.

References:

Weigman, Bernard J. and Spiegel, F. Xavier: "An Automated Data Collection System for a Charpy Impact Tester ", NASA CP-3201, 1992.

Eggebrecht, L.C.: *Interfacing to the IBM Personal Computer*, Howard W. Sams & Co.

Thompson and Kuckes: *IBM-PC in the Laboratory*, Cambridge University Press.

Krutz, Ronald L.: *Interfacing Techniques in Digital Design*, Wiley.

Stone, Harold S.: *Microcomputer Interfacing*, Addison Wesley.

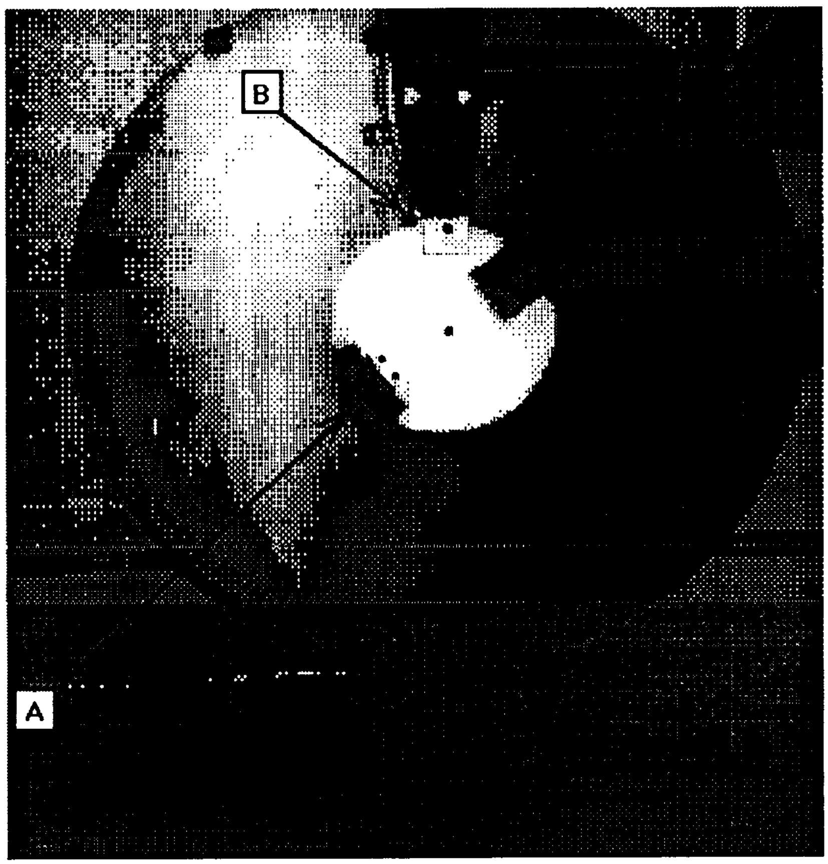
Cripps, Martin: *Computer Interfacing - Connection to the Real World*, Edward Arnold Publisher (Hodder & Stoughton).

Spiegel, F. Xavier and Weigman, Bernard J.: " An Automated System for Creep Testing" , NASA CP-3151, 1991.

Fellers, William O.: *Materials Science, Testing and Properties for Technicians*, Prentice Hall, 1990.

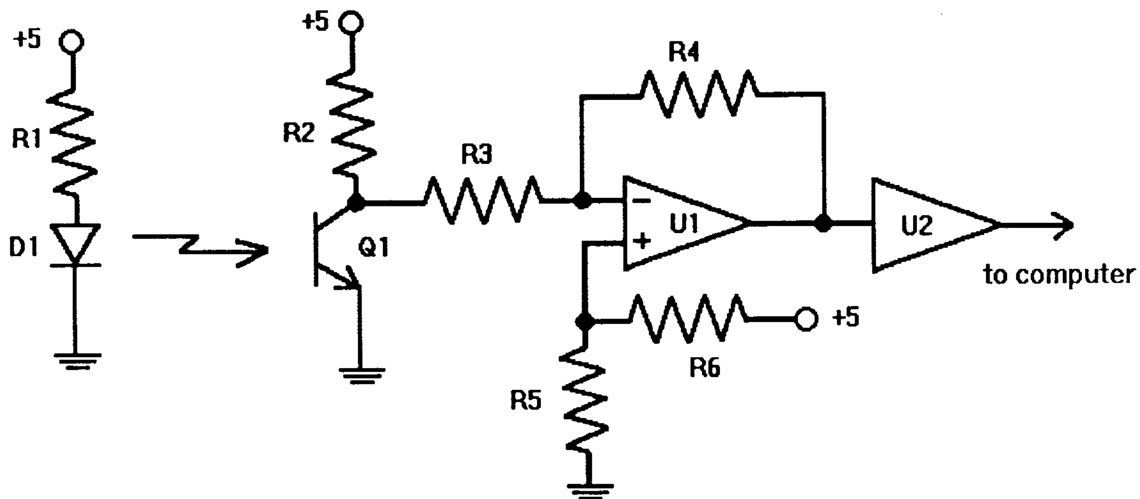
Sources of Supplies: The resistors and integrated circuits used here should be common stock to any electrical engineering/ computer science department. The IR emitter/receiver pair is available through Radio Shack. The mounting saddle for the light link is tooled from scrap wood. The optical disk is made from ordinary 0.125" sheet aluminum.

Appendix 1



The optical system consists of the white metal disk centered on the pendulum's axle and rigidly attached to the pendulum, the light source/sensor which straddles the disk (B), and the interchangeable slit plate (A). When the pendulum is near the bottom of its swing, the slit plate will be passing through the light source/sensor. The pulse train issued by the light sensor is routed to conditioning circuitry (Appendix 2) and then to the digital input board in the PC.

Appendix 2 - Light Sensor and Signal Conditioning Circuitry



R1 = 270 Ω

R2 = 2000 Ω

R3 = 3000 Ω

R4 = 30000 Ω

R5 = 3000 Ω

R6 = 3000 Ω

U1 = LM324 Quad OpAmp

U2 = SN7404 Hex Inverter

D1/Q1 = Generic IR source/receiver pair (Radio Shack)